Challenging pre-galilean misconceptions through alternative visualizations

Estelle Blanquet, Eric Picholle

CHALLENGING PRE-GALILEAN MISCONCEPTIONS THROUGH ALTERNATIVE VISUALIZATIONS

Estelle Blanquet[1,2] *and Eric Picholle*[3]
[1] IUFM de Nice Célestin Freinet, Université de Nice Sophia-Antipolis, 43 avenue Stephen Liégeard, 06100 Nice, France. Estelle.Blanquet@unice.fr
[2] Laboratoire de Didactique et d'Epistémologie des Sciences, Université de Genève
[3] CNRS LPMC, UMR 6622, Université de Nice Sophia-Antipolis

Abstract: While duly Copernican, a significant part of primary school teachers-in-training fail to see the point of the (Galilean) principle of relativity. Two inquiry based teaching sequences involving the notion of reference frame were designed to challenge the students' robust pre-Galilean misconceptions, without mathematical requirements. The first sequence makes use of an artist view ("Framed Earth", by Manchu, 1989) and literary representations of the Earth as seen from a lunar point of view. The second one deals with the succession of seasons through analogical models of the Earth/Sun system. Both sequences were tested among future primary school teachers. Half the cohort was only exposed to the latter sequence while the other half experimented both. Artist representations appear to be an effective way to challenge misconceptions where direct experimentation is not available, such as in astronomy problems.

Keywords: Frame of reference; Misconceptions; Principle of relativity; Artist view; Science fiction

INTRODUCTION

While scientifically closed for four centuries, the issue of heliocentrism still puzzles many a layman, to the point that it is now a common cliffhanger for journalistic discussions of scientific literacy. Many studies have established that a small but significant part of the population (typ. 20% — Gallup, 1999) still remain pre-Copernican, and bringing someone to admit that he believes in the Sun revolving around Earth has become a recurrent joke in mass media.

Pre-Galilean conceptions — namely, the existence of a privileged referential, whether heliocentric or geocentric — are even more widely shared. Saltiel (1980) has shown that for most students, "*proper motion and immobility are defined intrinsically, and not with respects to specified bodies and frames.* (…) *Motion and rest are thus fundamentally inequivalent, a typical pre-Galilean view*". Galilean relativity is classically taught through the mathematical exercise of changing the reference frame. Typically, one can then compare the apparent motion of Mars as seen either from the Earth or from the Sun. Students at ease with mathematical tools (namely spatial geometry) or with good spatial visualization skills (Kozhevnokov & al., 2007) thus integrate painlessly the Galilean paradigm, while otherwise bright students, typically of literary background but with a weakness in maths, often fail to even acknowledge the problem, ancient and conceptually simple as it may be.

This pedagogical difficulty is almost as old as Copernicanism itself. One strategy calls on one's "suspension of disbelief", through thought experiments and, more generally, fiction

(Picholle, 2006). It was first developed by Johannes Kepler to overcome the Ptolemaic prejudice. Kepler was probably first both to publish a formal mathematical analysis of the apparent motion of Mars (in *Mysterium Cosmographicum*, 1596) and, considering its public reception (or lack thereof), to try and bypass formalism through a *literary* thought experiment, the *Somnium* (*The Dream, or Lunar Astronomy,* written ca. 1609). Nowadays, while geocentrism is no longer a sensitive issue, estrangement (Parrinder, 2000) and extraction could still ease off the acceptation of an arbitrary point of view.

In the spirit of Kepler's strategy, the aim of the present study is to investigate the impact of contemporary fiction and artist views to help future teachers to overcome their own prejudices.

PRE-GALILEAN TEACHERS?

Many primary school teachers feel uncomfortable with the idea that, from a terrestrial point of view, the Sun rotates around the Earth. To quantify the prevalence of the Relativistic (*i.e.* Galilean) conception of the Solar system, we submitted 99 graduate students to a questionnaire: *"Two persons are discussing. One claims that the Earth rotates around the Sun and the other the opposite. They ask for your opinion. What do you answer? How do you know?"*

Fourteen different majors were represented, including twelve "experts" in physics (M1 of Master in Physics Teaching). All of them had theoretically been taught on the relativity of motion at least at secondary school level. If the Ptolemaic view is absent, the Copernican view is widely shared (> 90%) but seldom justified by scientific arguments: '*I learned it in school'* (26) / *'Because all planets turn around the Sun'* (18). On the other hand, the minority Galilean view (7/99) was always properly justified: '*Both can be said, it depends of the point of view*'. While physics "expert" students tended to favour the phrase "reference frame" over "point of view", only 1 out of 12 used it properly.

GRASPING RELATIVITY: GEOMETRY ISN'T ENOUGH

Two families of obstacles to the understanding of the Galilean paradigm by the students can be identified. One is technical (namely, mathematical), and associated to the capacity to juggle between points of view (Saltiel, 1980). But there is also a Bachelardian epistemological obstacle: *the reluctance to admit that all reference frames can be equally legitimate* (associated or not to a "natural locus"-like Aristotelian prejudice), even when one can juggle between different points of view.

Our hypothesis is than the latter (epistemological) obstacle is involved in the rarity of the Galilean view. Specific work on the physicality of alternate points of view is thus necessary to overcome it.

METHODOLOGY

The training of future primary school teachers normally includes a inquiry-based learning sequence on Astronomy, involving a discussion of the relative position of Earth and Sun through the traditional problem of the succession of seasons on Earth.

We followed the example of Kepler's *Somnium,* in which a narrator describes his trip on the Moon. Looking through his eyes, the reader is then brought to accept the Lunar point of view as physically legitimate. We designed inquiry sequences implementing this idea through contemporary science fiction works, both literary excerpts and artist views.

In combination with a sequence on the spatial relationships involved in Earth seasons, emphasizing their geometrical reciprocity, they allow to tackle both obstacle families.

"Framed Earth" sequence

The "Framed Earth" sequence (Blanquet, 2011) first involves a painting from French artist Manchu (1989), reproduced in Fig. 1.

Manchu's realistic art suggests a stationary Earth in Moon's sky and raises questions: *Does the Earth stay in the frame? Can Moon's inhabitants observe all the parts of the Earth? Do they see Earth' phases? Where are they on the Moon?* Using their previous knowledge about the Moon, students can conclude with adequate questioning and reformulations from the facilitator. During the process, corporal motions and direct visualizations of analogical models facilitate the representation of several Lunar points of view, thereafter readily accepted as legitimate.

Fig. 1: "La Frontière éclatée"

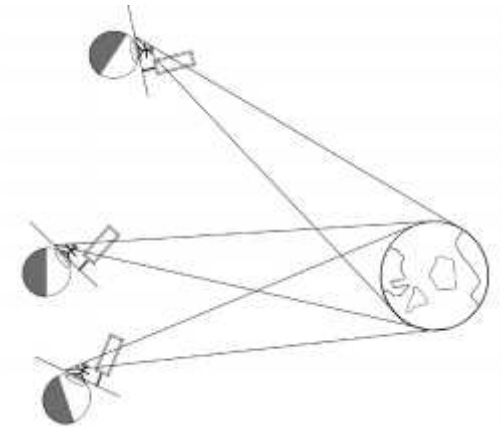

Fig.2: Schematic explanation of the Earth remaining in the Frame

Additionally, excerpts from short stories allow independent tests of students' views through distinct thought experiments: they have to identify hints of Earth's appearance and behaviour and to check them against what they had discovered during the course. They were also brought to discover how Earth's terminator could be used as a clock from the Moon.

A typical excerpt reads:

> 'Like all the best hotels, the Zurich is in Pressure One on the west side so that it can have a view of Earth. I helped Miss Brentwood register with the roboclerk and found her room; it had its own port. She went straight to it, began staring at Earth and going ooh! and ahh! I glanced past her and saw that it was a few minutes past thirteen; sunset sliced straight down the tip of India — early enough to snag another client. "Will that be all, Miss Brentwood?" (…) The view on that side is monotonous except for Earth hanging in the sky.' (Heinlein, 1957)

"Seasons" sequence

Since few primary school teachers-to-be have an advanced scientific background, the usual astronomical sequence also avoids mathematic difficulties by using analogical models (polystyrene balls to represent the planet, etc.) and bodily motions.

Taking into account the phenomena visible from Earth (apparent motion of Sun and stars), the trainees have to propose different models and to discuss their validity, without ever using either the common sense or the authoritative arguments. Alternating points of view, they are brought to acknowledge the geometrical reciprocity of various solar system models and to reconsider their position about the relativity of the motion of Earth and Sun. Previous acceptance of the legitimacy of the Lunar point of view strengthens the physical legitimacy of terrestrial point with regards to the heliocentric one.

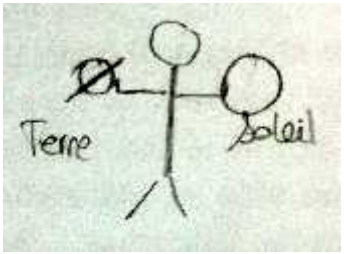

Fig.3: Inclining the Earth' axis to explain alternate seasons in Northern and Southern hemispheres (student drawing)

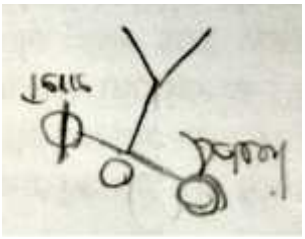

Fig.4: Same as Fig. 3. Inclining the Sun (alternate explanation from the same student)

Assessment methodology

The same questionnaire as above was submitted to a second group of 93 students (M1 Master of « primary school Teaching », none of them Physics majors) after they experienced the "Framed Earth" sequence (with teacher A). They then experienced the "seasons" sequence. Two weeks later, a more detailed questionnaire including slightly different formulations of the same question was asked for comparison (with two different teachers A and B). All sequences were audio- and video-taped for transcription and analysis.

DESTABILISATION OF MISCONCEPTIONS

The "Framed Earth" sequence alone doesn't appear to significantly affect students' initial conceptions. In combination, the two sequences appear to yield significant progress towards the Galilean paradigm. No dependence on student's previous major was observed. Yet, while further studies would be necessary to assess the robustness of this approach, available results suggest that it may be significantly teacher-sensitive method.

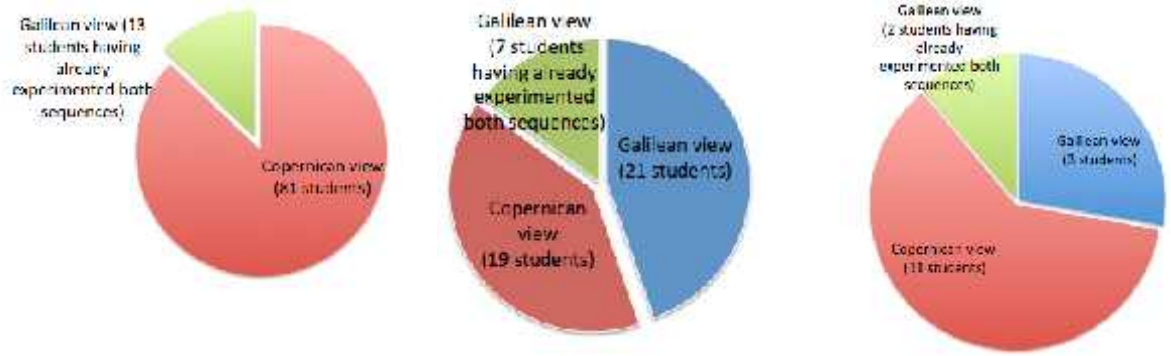

Fig.5 (a): Students' view after the "Framed Earth" sequence only (93 students) **(b) *idem* after both sequences (Teacher A, 47 students)** **(c) *idem* Students' view after both sequences (Teacher B, 18 students)**

CONCLUSION

Artist representation appears to affect the expression of paradigmatic misconceptions and to contribute to modify them, at least in this specific case. Considering the robustness of pre-Galilean misconceptions, this is already a significant step. The cognitive processes involved in fiction thus appear as a promising (albeit not autonomous) tool to help overcome epistemological obstacles related to physicality. The ability to imagine oneself in another frame of reference, using artist's visualization also seems an efficient alternative to introduce the principle of relativity to a public without regard to it mathematical literacy.

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